GUEST EDITORIAL: ON INTELLIGENCE "ARTIFICIAL" OR OTHERWISE

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THE neuron constitutes the fundamental physiological unit underlying all animal behavior that could in any way be considered as reflecting intelligence. This basic unit, once having evolved from precursor organelles, has remained suprisingly constant throughout the wide diversity of life forms in the animal kingdom. Our understanding of the evolution of intelligence as a behavioral characteristic of animals must be based on a knowledge of the fundamental unit and the principle that the basic structure and mechanism of function of that unit has remained essentially constant with variation relating primarily to an increase in numbers of units and complexity of the connections between them.

THE NEURON

A typical central nervous system neuron consists of a cell body with a complex arborization of relatively short branches or dendrites, and gives rise to a single prolongation or axon of varying lengths sufficient to reach from the central nervous system to the most distal effector organ as, for example, in the human, from the lower spinal cord to the muscles of the foot. There are, of course, a multitude of specialilzed forms and types of neuron, but the same general principles apply to all. This basic prototypical neuron has only two possible physiological modes of action open to it: it may fire or not fire. That is to say, it can initiate by a change in membrane polarization an action potential which will travel the length of the axon and, arriving at its termination, cause to be released a chemical mediator that will result in a response determined by the nature of the cell to which the axon abuts and by the specialized character of the firing neuron itself. For example, should the axon terminate on a muscle fiber, it will provoke a contraction of that

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fiber. Should it terminate on the cell body or dendritic tree of another neuron, it might, depending on its own inherent quality, either promote depolarization of the second neuron (stimulate) or favor a hyperpolarization and thereby inhibit firing of the second cell.

So far we have described a simple biological unit of microscopic but significant size, existing in a variable but finite number in any given organism. In the human brain a typical neuron may have several tens of thousands of axons abuting on the cell body and its dendritic prolongations, any number of which at a given moment in time may be either "silent" or active and favoring either stimulation or inhibition. Furthermore, these incoming axons may themselves be acted upon by equal numbers of inputs with the same variability. When a critical level of stimulating inputs has been reached at a specific moment in time the cell will fire, which is the only action it is capable of. Until that time it will remain nonfiring or "silent," that being its only alternative response.

From Simple Switches To Thought And Action

A single neuron in the human brain, while itself being only capable of responding or not responding, when one takes into account its tens of thousands of inputs and considers as a basic functional unity all of the cells which themselves contribute to those inputs, together with their own inputs and interconnecting outflows, becomes a highly complex network which provides the substrata for thought and physiological action. Taking, for example, a "simple" human act such as lifting an apple from a table, appropriate specialized neurons in the human brain must first respond to the visual input which in turn stimulates appropriate memory mechanisms allowing for recognition and identification of the object as well as its localization in space and other groups of cells necessary to formulate the desire and intention of executing the act. This must involve verbal and language areas, extensive memory circuits that might include all sensory and motor neurons that may have been involved in a childhood fall from an apple tree, etc. When all of the requisite areas have directed positive stimulating influences on those neurons whose ultimate functions control the movement of limbs and the necessary balancing mechanisms of the body, the simple volitional act may be effectuated. It is obvious now that the accomplishment of such an act requires a vast number, if not the quasitotality of the existing brain neurons.

While some 10 billion neurons provide the infrastructure allowing for the great diversity of human undertakings from the picking up of an apple to the composition of a symphony or for descending three steps that might lead from a space ship to the moon, the underlying physiological unit or neuron is in no way qualitatively different from those in a termite, a turtle or a titmouse.

The Evolution Of Thought

In the simplest of multicellular animals a fundamental neuron not unlike our own may respond to a limited number of sensory receptor inputs to cause its owner to move away from some noxious stimulus or toward a nutritive one. It has been shown that even simple worms are capable of "learning," implying the function of acquired memory. As the behavior patterns of these organisms are clearly species specific, inherited memory patterns or instincts must be built into the organizational structure and chemistry of these rudimentary nervous systems. At the level, say, of a termite, these same basic building blocks have achieved an adequate level of complexity and numbers to allow for the programming of an extremely complex series of behavior patterns that underly the construction of comparatively enormous edifices and an intricate social community.

Moving upward in animal development, a progressively increasing number of basic neurons, together with more and more complex interconnecting loops and progressively specialized internal structures, has allowed for progressively greater amounts of experiential learning, storage and independence of thought. While it is of course impossible to say exactly when this independence of thought appeared, it is obvious that in the course of development, at some point a critical mass of underlying basic units with their interconnections is achieved, allowing for progression from entirely preprogrammed behavior to a beginning level of autonomy. We know by experimentation that a mouse exposed to an enriched environment manifests objective evidence in brain weight and chemistry, indicating that it is actively interacting with the environment and on some level making decisions. No one attempts to deny that dogs and cats are capable of independent thoughtful behavior with meaningful vocalization and communication. Higher primates may well be capable of symbolic communications that qualify as language. At no point in this continuum can one say "intelligence" starts here, and at no time are the fundamental building blocks capable of more than an "on - off" response.

We Humans

If we participate in this continuum with building blocks essentially in all ways similar to our inverbrate ancestors, what then is human individuality or "soul?" It would appear that after achieving a critical mass of neuronal structures adequate to sustain independence of thought, that is to say, observing environmental changes and storing such information in a manner that can be subsequently utilized and applied to similar but different situations, new and unprogrammed behavior becomes possible. At that point the rudimentary process of thinking becomes independent of the underlying physiological infrastructures, and may be considered as a new and independent entity which one might call the *anima*. Again we have a continuum of progressing complexity running pari pasu with the increasing neuronal mass with animals at each level of development having that degree of independence of thought or *anima* permitted by the number and complexity of their central nervous systems. For humans to have imagined that they possess some qualitative difference distinguishing them from the developmental steps that went before can only be equated to the pre-Copernican concept of the universe with ourselves as its center.

We have yet fully to elucidate how much of our own behavior is preprogrammed. If we can accept that this ego which we so highly prize is shared, albeit in simpler form, with all organisms capable of original thought it becomes easier to accept that the inherited structure of our nervous system which predisposes us to the acquisition of speech may also have profound influence on a multitude, if not all, aspects of human behavior.

And What Of Machines

The basic building blocks of our "thinking" machines are simple units capable of only two responses, to fire or not to fire in a manner not unlike the prototypical neuron. This fundamental response can now be made to depend upon the summation of thousands of inputs. The performance of "behavior" of these machines enables the performance of highly complex activities which might be on the same level in human terms that construction of a termite colony might be in their frame of reference.

At some point we must assume that a critical mass of transistors will exist, permitting independent modification of preprogrammed behavior based on newly acquired data. When this and the subsequent logical steps occur, we shall have to admit that these machines are capable of thought and, as we postulated for animals, an *anima* will have been created that will be independent of its underlying physiological infrastructure. In the sense that they cannot replicate themselves, they of course are not alive. However, to the extent that we believe that our individuality is more than the simple functioning of ourselves and sinews, these machines will also have to be considered as being personalities in their own right.